Use of a miniature infrared COTS sensor in several military applications

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ABSTRACT

The proliferation of small infrared cameras in high-volume commercial applications (e.g. firefighting, law-enforcement, and automotive) presents a tremendous opportunity for truly low-cost military micro-sensors. Indigo Systems Corporation's UL3 Omega™ camera is a commercial off-the-shelf (COTS) thermal imager that offers ultra-small size (3.5 in^3), light weight (102g), and low power (< 1.3 W). It employs a 164x120 microbolometer focal plane array (FPA) and is currently entering full-scale production. Furthermore, a 324x240 upgrade is in development. While aimed primarily at the commercial market, small size and low-power consumption make UL3 well-suited for other applications, including miniature unmanned aerial vehicles (UAVs) weapon-sights, and unattended ground sensors (UGS). This paper focuses on the key features of the UL3 family of miniature IR cameras and their utility in soldier systems.

Keywords: uncooled, infrared, low cost, thermal sensor, UGS, UGV, UAV, weapon-sight

1. INTRODUCTION

Indigo Systems is a pioneer in the miniature IR camera market, having begun development of its UL3 product line in 1997. The name UL3 stands for Ultra-Low Size, Ultra-Lightweight, and Ultra-Low Power. This family of uncooled microbolometer cameras has opened exciting new opportunities for the application of infrared technology in important commercial applications such as fire-fighting, security/surveillance, and predictive maintenance. UL3 also provides critical new technology to advance the effectiveness of man-portable military systems and micro-sensors. Aspects of Indigo's UL3 development were partially funded by the U.S. Army Night Vision Electronic Sensors Directorate (NVESD). The underlying strategy behind the Army's investment was to leverage a successful commercial off-the-shelf (COTS) sensor for use in military applications. This strategy allows the U.S. Government to obtain cost savings and risk reduction by capitalizing on larger commercial market volumes. Furthermore, development of military systems that are based on a COTS sensor allows rapid system upgrade as the product line naturally evolves toward higher performance and lower cost.

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Figure 1 depicts the growth plan for Indigo's UL3 microcamera family. The first UL3 product was the Alpha™ camera, which went into production in 1999 as the world's smallest, lightest, lowest-power infrared camera. Its successor is the Omega™ camera, which is currently entering full-scale production. Omega™ improves on every aspect of the already-successful Alpha™ design. Power consumption has been reduced by nearly 15% (from 1.5W to 1.3W), weight by 45% (from 186g to 102g), volume by 60% (from 8.7 in^3 to 3.5 in^3), and NEdT by approximately 20%. Figure 2 shows the two cameras side-by-side, and Table 1 compares specifications.

Currently in development is a mid-format upgrade (320x240) to the Omega™ design. Because Omega's signal processing electronics are extremely adaptable, only software modifications and additional memory will be required to transition to the mid-format product. Therefore, the mid-format camera will be only slightly larger than the small-format Omega™. In addition to the microbolometer products, the UL3 family also includes Near Infrared (NIR) sensors employing InGaAs arrays. The NIR products are intended primarily for the telecommunications industry, but there is also potential for military utility.

Figure 1: UL3 product line. *Now in production, the Omega™ camera is an improvement of the successful Alpha™ design.*

Figure 2: Alpha™ and Omega™. *Omega™ is significantly smaller and lighter than its predecessor.*

Table 1: Alpha™ and Omega™ specifications

	Alpha™	Omega™
Weight (w/ 18 mm lens)	186 g	102 g
Dimensions (w/out lens)	1.7" x 1.7" x 3.0"	1.4" x 1.3" x 1.9"
Volume	8.7 in^3	3.5 in^3
Power Consumption	≤1500 mW (room temp.) ≤2500 mW (extreme temp.)	≤1300 mW
NEdT at f/1.6	≤ 100 mK	≤ 85 mK
Temp. Range	0°C to +55°C	-40°C to +55°C

2. OVERVIEW OF THE OMEGA™ CAMERA

The essential foundation to the small size, weight, and power of the UL3 cameras is state-of-the-art readout integrated circuit (ROIC) design and novel electronics packaging concepts. For example, non-uniformity correction (NUC) performed on the focal plane array (FPA) facilitates greater dynamic range and sensitivity. The high sensitivity of the FPA in turn supports slower, more compact optical designs than those typically found on uncooled thermal sensors. Figure 3 shows the three standard f/1.6 lens assemblies available for Omega™, and Table 2 provides specifications for each. Indigo also plans to offer an f/1 lens option for applications that demand very high sensitivity as well as a 9-mm focal-length option for wide field-of-view applications.

Figure 3: Three standard f/1.6 lens options. *Omega™ lenses are interchangeable in the field.*

Table 1: Specifications for the f/1.6 lenses.

Focal length	11mm	18mm	30mm
FOV	40°x30°	25°x19°	15°x11°
f/#	f/1.6	f/1.6	f/1.6
Min. focus	0.1 m	0.3 m	0.3 m
Length	1.1”	0.9”	1.4”
Weight	33 g	26 g	38 g

Another driver of cost, size, weight, and power reduction on the Omega™ camera is the lack of a Thermoelectric Cooler (TEC). Most uncooled cameras need a TEC to hold the FPA at a stable temperature because the output would otherwise vary radically (and non-uniformly), causing undesirable image artifacts. However, Omega™ employs a novel combination of on-focal-plane circuitry and NUC processing to eliminate the TEC. The unique approach to TEC-less operation, which is currently patent-pending, enables the camera to operate over a very wide temperature range while maintaining excellent dynamic range and image uniformity.

Removing the TEC greatly reduces the cost and complexity of the camera, allowing a smaller vacuum package, simpler electronics, and simpler unit assembly. Power consumption is also decreased, while the operating temperature range of the camera is expanded. Furthermore, TEC-less operation means that the system can begin imaging almost immediately after turn-on rather than waiting for FPA temperature to stabilize.

3. MILITARY APPLICATIONS OF UL3

Its small size, light weight, and low-power consumption make the Omega™ well-suited for many traditional military applications as well as some exciting new ones.

UAVs: Miniature unmanned aerial vehicles (UAVs) provide a straightforward, fairly low-cost capability to perform reconnaissance, search, surveillance, and battlefield assessment without exposing personnel to hostile fire. Infrared imaging expands the utility of these systems by allowing nighttime missions and better penetration of smoke. However, miniature UAV systems demand miniature sensors. Furthermore, since the vehicle must also carry batteries for the payload, low-power expenditure is also an essential requirement. Reducing weight and power of the sensor payload translates directly to longer flight duration.

The small size and low power consumption of UL3 cameras make them a natural fit for miniature UAV systems. The Alpha™ camera has been flown on numerous platforms, including vehicles manufactured by AeroVironment (see Figure 4), BAI Aerosystems (Figure 5), and Schiebel (not shown). Figure 6 shows imagery obtained during flight aboard one of these. Not surprisingly, the Omega™ camera's improved performance has generated much interest in the miniature UAV community, and an initial flight is planned imminently.

Figure 4: A hand-launched AeroVironment UAV.

Figure 5: A UAV manufactured by BAI Aerosystems.

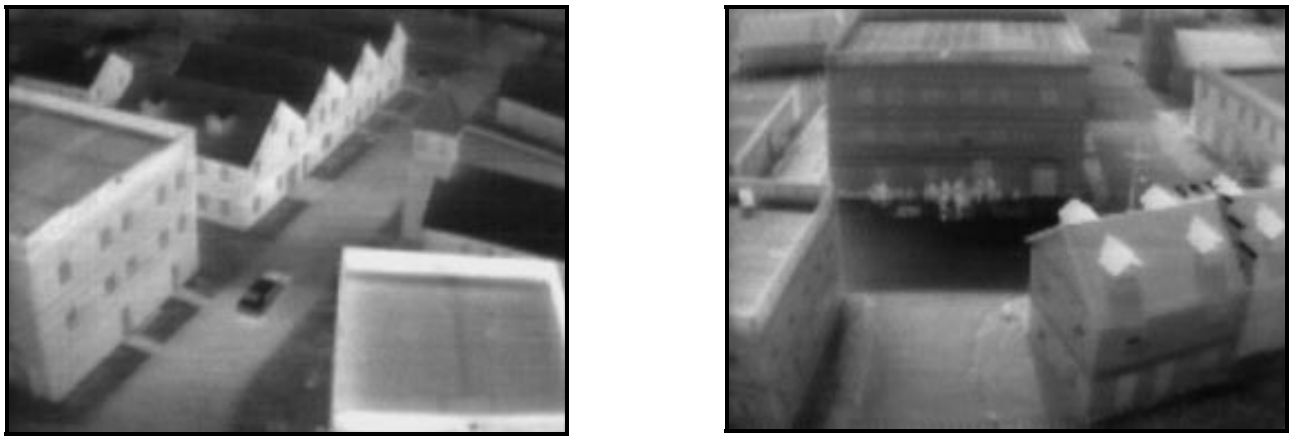

Figure 6: Alpha™ images during a night flight of the Camcopter UAV.

UGVs: Robotic unmanned ground vehicles (UGVs) are another potential application of the UL3 product line. Figure 7 shows two UGV systems developed by iRobot – the ATRV-Mini, an all-terrain robotic vehicle capable of carrying multiple sensors, and another vehicle intended for urban operations. Potential applications for vehicles such as these include mine search and reconnaissance of potentially dangerous territory. Just as with the mini UAVs, volume and power are at a premium on these vehicles, particularly since the payload often consists of a sensor suite rather than a single device. The Alpha™ camera has been previously installed on UGV systems, and multiple manufacturers have expressed interest in offering the Omega™ camera as a payload option.

Figure 7: UGV Systems by iRobot.

Weapon-sights: Figure 8 shows a conceptual design for an Omega™-based weapon-sight. This concept was developed by Indigo Systems in collaboration with Insight Technology. The sight includes an integral battery compartment, user controls, and a rail-mount. It is intended to interface with a helmet-mounted display (HMD). Battery life of the system using 4 lithium AA cells is projected to be almost 10 hours. The design is compact (5.7" x 1.8" x 1.6") and weighs only 1.1 lbs. (495 g), including the batteries. Ultimately, this same mechanical design will facilitate the mid-format upgrade to Omega™ with only a slight growth in volume (approximately 0.5" height increase).

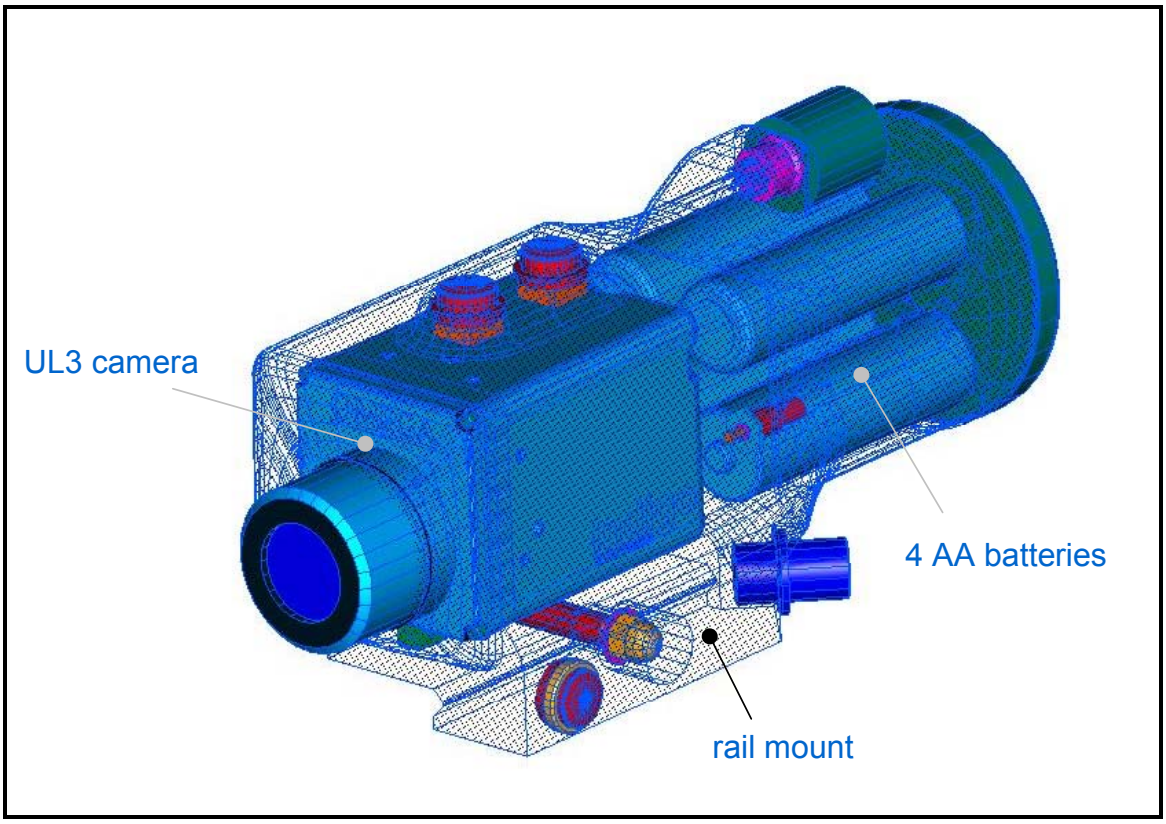

Figure 8: Conceptual design of a weapon-sight based on Omega™.

Soldier-mounted cameras: In addition to weapon-sights, there is potential to mount a sensor as small as Omega™ elsewhere on the soldier. For example, integrating Omega™ with night-vision goggles (NVGs) or integrating a helmet-mounted camera with an HMD would improve soldier mobility and stealth during night operations. Similarly, integrating Omega™ into a glove or wrist-strap might prove useful for peering around corners or over obstacles. Hands-free thermal imaging provides the soldier with the ability to navigate in darkness and to detect potential pitfalls and ambushes without sacrificing dexterity and comfort.

UGS: Indigo has developed the system architecture for an unattended ground sensor (UGS) suite based on UL3. The objective is an UGS sensor that is lightweight, easily deployed and that provides wide field-of-view coverage for long operational periods with no external support. Figure 9 illustrates the major elements of the total system. An UGS unit is placed in conjunction with a perimeter array of seismic, magnetic, acoustic and other trip sensors. These sensors are used to cue the UGS to collect snapshots, which are linked back to a base station via an RF link. The complete system includes multiple UGS units, each with their associated cueing sensors, positioned to cover the full expanse of the area under surveillance. The UGS unit itself is illustrated in Figure 10. Its key hardware elements include the following:

- A UL3 camera, re-packaged to fit in a cylindrical housing
- A pointing motor to rotate the sensor line-of-sight
- Transceiver / data processor electronics to poll the cueing sensors, to determine the point direction when the cueing sensors are tripped, and to compress/transmit infrared imagery
- An aluminum housing that can be staked into the ground
- Batteries to power the entire unit

A major design driver is the requirement to operate autonomously on the same set of batteries for several months after emplacement. To reduce steady-state power, the sensor can be set to a very low-power standby state (< 10 mW) most of the time. Only when the data processor detects an intrusion is the UL3 commanded into its imaging state. Consequently, one of the essential requirements for the camera when operated in standby mode is “instantaneous on” capability.

The UGS system design is based on a mid-format upgrade to the UL3 camera that features a very rapid turn-on. The key to faster turn-on time is an independently-powered circuit on the FPA that remains powered while the rest of the camera is off; this subset of the ROIC electronics reduces the settling time when the camera is brought to life.

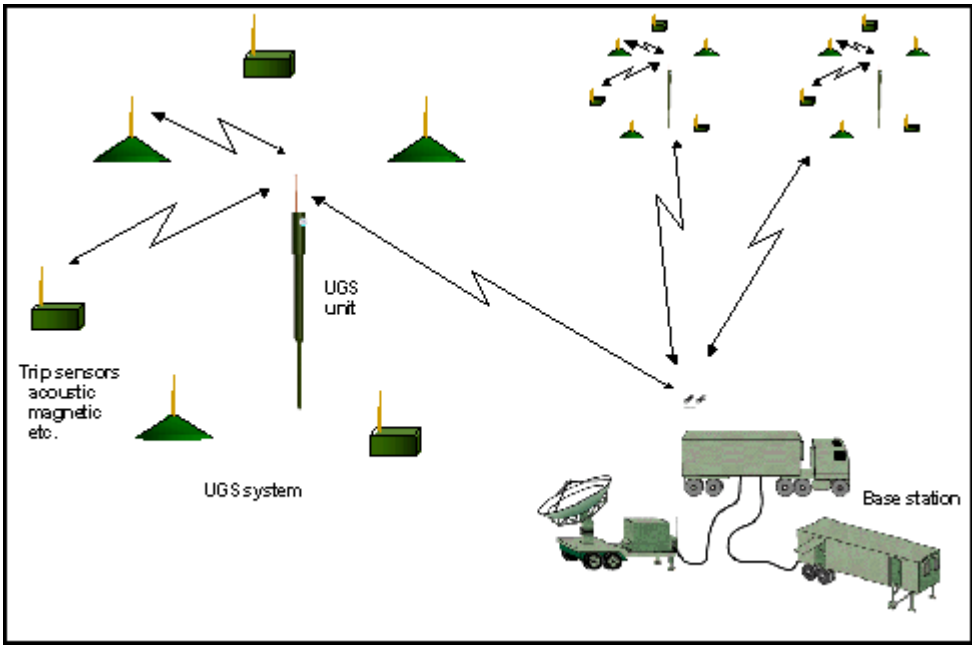

Figure 9: A total UGS sensor suite.

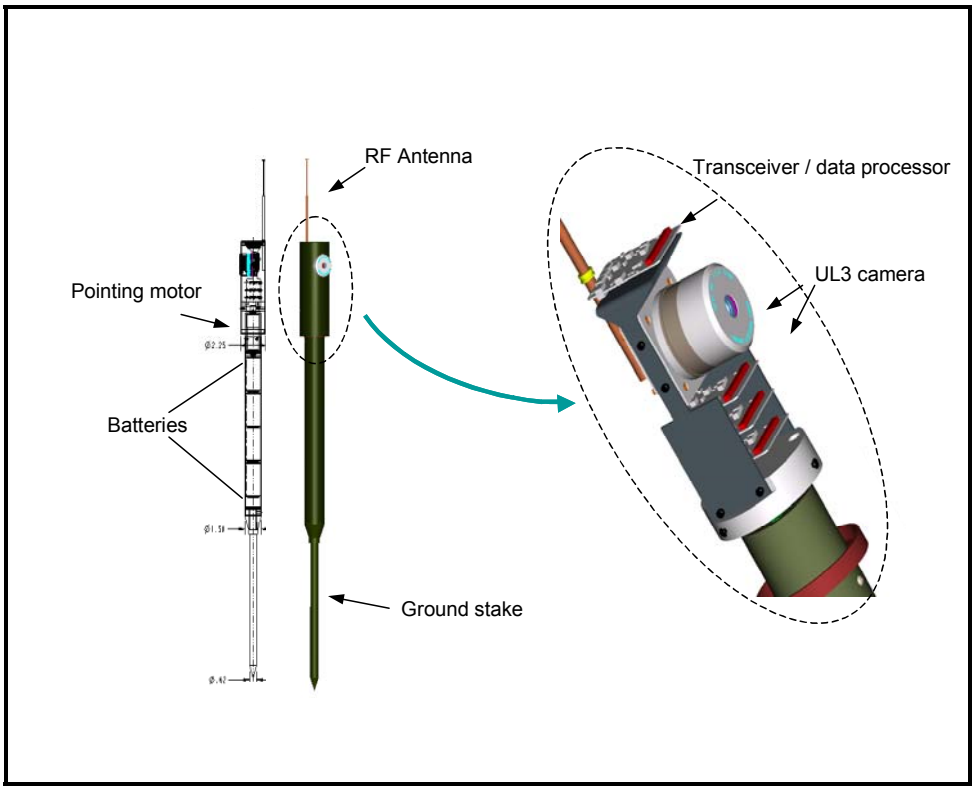

Figure 10: Key components of the UL3-based UGS unit.

4. SUMMARY

Indigo System's UL3 family of miniature IR cameras are a natural fit for many military applications requiring portability and long battery life. The Alpha™ camera has been installed on rifles, on various UAVs, and on UGV systems. The Omega™ camera, which improves on almost every aspect of the Alpha™ design, also has potential for similar applications. Indigo Systems is under contract to develop a mid-format upgrade to the Omega™ camera which will be the heart of an imaging UGS system.

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Finally, we wish to thank Insight Technology Inc. for contributions to the conceptual weapon-sight design shown herein.